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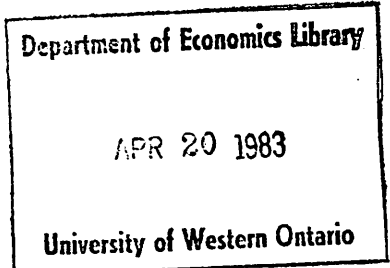
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PRODUCT DURABILITY, CAPACITY AND
ENTRY DETERRENCE*

by

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ABSTRACT

This paper examines the role of capacity in a model of a durable good producer facing an entry threat. If capacity decisions are made in advance, a low level of capacity helps commit the firm to low future levels of output if it is a seller. But a high level of capacity helps deter entry, or create a more profitable post-entry equilibrium for the established firm. A simple two-period model is developed, in which the optimal policy for the established firm can be explicitly solved in terms of the parameters of the (linear) cost and demand functions. Among the results, it is shown that an entry threat can make selling a durable good more profitable than renting, which is the opposite conclusion from that derived for a durable good monopolist.

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1. Introduction

There has been much interest in the past few years in the role of capacity in entry deterrence. Established firms can affect the payoffs to some post-entry game through capacity decisions in most of the recent models of entry deterrence. Since established firms are hypothesized to make capacity decisions prior to the entry decision, they have a first-mover advantage. As Dixit (1980) notes, "the established firm can exercise leadership over a limited range by using its capacity choice to manipulate the initial conditions of the game" (p. 99). However, the model is essentially atemporal. The established firm does not necessarily produce any output before the entry decision; the asymmetry which gives the established firms its advantage is that it has the first move in the game-theoretic sense. Spulber (1981) presents a model with an explicit time structure, where the established firm has a monopoly in the first period and faces an entry threat in the second period. But demands in the two periods are unrelated, so that the only influence of the pre-entry phase on the post-entry phase is through capacity.

Here a model is presented in which the established firm can influence demand in the post-entry phase by its choice of pre-entry output. By flooding the market in the pre-entry phase, it can reduce the profitability of entry. Of course such actions will reduce its own profits so that entry deterrence may still not be worthwhile. But the fact that first-period sales are actually observed prior to the entry decision may make such "spoiling the market" a much stronger commitment than investment in capacity, or some threat which may not be plausible.

The reason for the interdependency in demand is that the good being produced is durable. Thus the price in the post-entry period is a function of the cumulative production. Output is also limited by capacity, as in the simple models of Dixit (1980) and Spulber (1981, Section I). Thus this model follows a suggestion of Stokey (1981), who notes (p. 128) "in the market for a durable good, the advantages of increased capacity to deter entry must be weighed against the advantages of restricting capacity to affect buyers' expectations".

These latter advantages have been analyzed by Coase (1972), Flath (1980), Stokey (1981) and Bulow (1982). Briefly, they stem from the dynamic inconsistency of the optimal plan of a monopolist who sells (rather than rents) the durable good. Having sold the initial period's output, such a monopolist will have incentives to increase future output beyond the levels which were perceived as optimal in the original plan, imposing capital losses on the buyers of the initial periods's output. Since rational buyers foresee these incentives, they will be willing to pay only the price associated with the consistent production path, rather than the higher price associated with the dynamically inconsistent optimum. Thus firms may wish to make some binding commitment to low levels of future output. If capacity is expensive (or impossible) to augment in future, a low initial capacity level may be such a commitment.

The offsetting advantages of increased capacity are familiar. High capacity reduces the established firm's future short-run costs. Thus its optimal post-entry output will be increased (regardless of the specific post-entry game). Such an increase will reduce potential entrants' profits, and may serve to profitably deter entry should fixed costs be high enough. (See Dixit (1980) or Spulber (1981).)

In this paper, a very simple model is presented in which these two rules of capacity can be examined. Although the integration of the two themes cited above may appear straightforward, the model yields several results which are due to the interaction between commitment and deterrence, and which do not arise in the simpler models. The established firm may be able to deter entry even when there are no fixed costs. The established firm may carry excess capacity in the second period, whether or not entry is deterred. With an entry threat, the commitment to buyers to low capacity is made more plausible. Even if capacity can be added in future (at no cost disadvantage), the established firm will never choose to do so. And when there is an entry threat, selling may be more profitable to the established firm than rental, whether or not entry is deterred.

All these results are presented in a very specific model. However, many of them appear to admit generalization fairly easily. In particular, the post-entry behavior may appear somewhat unusual. Discussion of this behavior is deferred to Section 3 below. Prior to this, the model will be solved for a monopolist with no entry threat. This exercise will be familiar to those who have read Bulow (1982), although it does demonstrate a difficulty that he was able to avoid by assuming zero capacity costs.

1. MONOPOLY WITH NO ENTRY THREAT

The world lasts for two periods. The future is not discounted. The good being produced is perfectly durable. The demand function for the services of the good is the same in each period, and is assumed linear. If there are Q units of the good available in some period, the rental price $\phi(Q)$ for the services of that good per period obeys

$$(1) \quad \phi(Q) = a - bQ \quad a, b > 0$$

The short-run cost function is "backwards L" shaped. Total costs of producing Q units, $TC(Q)$ are

$$(2) \quad \begin{aligned} TC(Q) &= mQ & Q \leq c \\ &= \infty & Q > c \end{aligned}$$

where c is capacity, and m a positive constant. Capacity which is installed before period 1 lasts for 2 periods, and costs $2k$ per unit, where k is a positive constant. For the moment, assume that no capacity can be added by the established firm for second-period production. The relaxation of this assumption will be presented in Section 2 below. Using the notation

$x_1 \equiv$ output in period 1 (by established firm)

$x_2 \equiv$ output in period 2 (by established firm)

$X \equiv x_1 + x_2$

$c \equiv$ capacity

A monopolist which rents out its output each period¹ would seek to maximize

$$(3) \quad \begin{aligned} \Pi &= (\phi(x_1))x_1 + \phi(X)X - 2kc - mx_1 - mx_2 \\ \text{subject to } x_1 &\leq c \\ x_2 &\leq c \end{aligned}$$

This maximization can be written as

$$(4) \quad \begin{aligned} \Pi &= (\phi(x_1))x_1 + (\phi(X) - m)X - 2kc \\ \text{subject to } x_1 &\leq c \\ X - x_1 &\leq c \end{aligned}$$

Given the linear form of the demand function (equation (1)), the solution to (4) is as in Table 1.² If capacity is cheap ($4k < a + m$) some capacity will be held idle in the second period. This result is due to the requirement that capacity be built for 2 periods; if less durable capacity were cheaper, the

monopoly renter might choose to have higher capacity in the first period. (But if capacity can be so easily built and removed, then the distinction between capacity costs and variable costs disappears.) If capacity is expensive ($4k > a + m$), the monopolist will not have excess capacity. Here the advantages of producing early (and earning two periods' rentals) are offset by the cost savings of intensive use of a low-capacity plant.

If the monopolist must sell its output, it would still like to implement the same production plan as the renter. Its problem is that, having already sold the first period's output, in the second period it will wish to maximize the value of second period sales, not the value of cumulative production. In the second period, it regards its own first-period output rather like a duopolist regards its rival's. It is assumed that the monopoly seller cannot commit itself in advance to a lower level of second-period output than it will find profitable in future. And buyers know this.

In the second period, then, the seller will pick an output level x_2 which maximizes

$$(5) \quad \Pi_2 = (\phi(x_1 + x_2) - m)x_2 \quad \text{subject to } x_2 \leq c$$

Note that implicit in (5) is the assumption that capacity cannot be augmented in the second period. Not surprisingly, the renter's optimal x_2 will not solve (5), if the renter's optimum involves excess capacity. For the renter's optimum will then satisfy $MR(X) = m$, which implies $\frac{\partial \Pi_2}{\partial x_2} = bx_1 > 0$ at the renter's optimum.

Of course, if the renter's optimum involves full use of capacity in the second period, the seller has no commitment problem. Table 1 shows this result occurs if capacity is expensive enough ($4k > a + m$). Solving the maximization

in (5) yields

$$(6) \quad x_2 = \min\left(c, \frac{a - m - bx_1}{2b}\right)$$

There are thus two ways for the seller to commit itself to low second-period output. It can invest in a low level of capacity in the first period. Or it can flood the market in the first period, reducing $\frac{a - m - bx_1}{2b}$. Of course, first-period output x_1 cannot exceed capacity. In fact, it will always be optimal for the seller to choose $x_1 = c$.³ The total profits of the seller (over both periods) can then be written $\phi(c)c + (\phi(c+x_2) - m)(c+x_2) - 2kc$, where x_2 satisfies (6). From (6), capacity will be binding on the seller in the second period if $c \leq \frac{a-m}{3b}$. Using this fact, total profits Π^s to the seller can be written

$$(7) \quad \Pi^s(c) = \begin{cases} \phi(c)c + (\phi(2c) - m)2c - 2kc & \text{if } c \leq \frac{a-m}{3b} \\ \phi(c)c + \left(\phi\left(\frac{a-m}{2b} + \frac{c}{2}\right) - m\right)\left(\frac{a-m}{2b} + \frac{c}{2}\right) - 2kc & \text{if } c > \frac{a-m}{3b} \end{cases}$$

Although each of the two functions on the right-hand side of (7) are concave, the left-hand derivative of $\Pi^s(c)$ is strictly less in value at $c = \frac{a-m}{3b}$ than the right-hand derivative.⁴ The existence of two local maxima cannot be ruled out. In such a case one maximum involves second-period output constrained by low capacity while the other involves high first period production and excess capacity in the second period. Differentiation of (7) indicates⁵ multiple local maxima exist when $8m - 2a \leq 12k \leq a + 5m$. For higher capacity costs ($12k > a + 5m$), there is a unique local maximum, involving full use of capacity. For lower capacity costs ($6k < 8m - 2a$), the unique local maximum involves excess

capacity. Further computation⁶ shows that when there are two local maxima, the excess-capacity solution is optimal if and only if $2k \leq m$ (i.e., when unit operating costs exceed unit capacity costs). The monopoly seller's optimum is shown in Table 2 and Figure 2. Note that Bulow (1982) assumes $k = 0$; thus the possibility never arises of the full use of capacity being optimal. Equation (8) of Bulow (1982) can be seen to be a special case of Table 2 here when $k = 0$.

The multiple local maxima imply a discontinuity in the seller's optimal policy when $2k = m$. At $2k = m$, the excess-capacity policy involves a higher level of capacity than the full-use-of-capacity policy. Both policies involve the same level of second-period output. Therefore the excess-capacity policy implies a lower rental price ($\phi(x_1 + x_2)$) in the second period. It will be more likely to deter entry. The following peculiarity arises: there are parameter values (for example, $a = 2.5$, $m = 1.0$, $k = .55$) for which the optimal policy for the monopoly seller involves full use of capacity. But it will not deter an entry threat. The other local optimum, involving excess capacity, is less profitable for the monopoly seller, but will deter entry. It thus may pay the seller to choose this latter policy when there is an entry threat. Although the entry threat will have altered the seller's policy, so that entry is blockaded, nonetheless the seller will find it optimal to set price strictly below the entry-detering level. The region where this phenomenon occurs is marked with an asterisk in Figure 5. Although a more detailed consideration of the seller's policy in the presence of an entry threat is deferred to Section 5, this example shows the conflicting roles of capacity in deterring entry and in commitment to first-period customers.

2. Capacity Can be Added in the Second Period

The above analysis assumed that capacity could be installed only at the beginning of the first period. Suppose now that capacity could be added at the beginning of period 2. Let αk be the unit cost of such capacity. If it is assumed that short-run capacity adjustments are more costly than long-run, then $\alpha \geq 1$, so that the per-period cost of capacity added in the second period is higher. Then the monopoly renter would never wish to add such capacity. For it would only wish to do so if its second-period marginal revenue exceeded $m + \alpha k$. But then so would its first-period marginal revenue, so that it would have paid the firm to have added capacity in the first period.

A monopoly seller will certainly only wish to add capacity in the second-period if it is constrained by current capacity (i.e., $x_2 = c$). Even then, such expansion is only warranted if $\phi'(2c)c + \phi(2c) > m + \alpha k$. From Table 2, this condition holds if and only if $a > 4m + (10\alpha - 6)k$. However, buyers would anticipate this expansion. And the seller would wish to alter its first-period plan if it knew of the availability of additions to capacity in the second period. As in the case of the renter, the monopoly seller will choose never to add any second-period capacity, if there is perfect foresight. If second period capacity were added, then optimality of x_2 implies $a - bx_1 - 2bx_2 = m + \alpha k$. This is inconsistent with an optimal choice of x_1 , when the firm anticipates an adjustment of second-period capacity and production to maintain the equality $a - bx_1 - 2bx_2 = m + \alpha k$.⁷

However, unlike the renter, the monopoly seller is affected by the possibility of adding second-period capacity, even though the capacity will not be built. If $a > 4m + (10\alpha - 6)k$, the seller must increase its first-period

output to prevent capacity from being added later. The new optimum involves $x_1 = x_2 = c = \frac{a - m - \alpha k}{3b}$. Figure 3 illustrates the optima for the case $\alpha = 1$.

The availability of second-period capacity lowers profits when $a > 4m + (10\alpha - 6)k$. When there are multiple local maxima, this availability increases the relative profitability of the excess-capacity optimum, since this policy makes future additions to capacity less tempting. Thus there are two somewhat paradoxical results of making capacity expansion easy for the seller. Profits are reduced. And the likelihood of unused second-period capacity is increased. Both results stem from the increased difficulty in plausible commitment to low future output by low initial capacity. And they can occur even when the less durable second-period capacity is arbitrarily expensive relative to the more durable first-period capacity.

Summarizing the results of Sections 1 and 2 concerning the role of capacity for durable goods monopolists:

PROPOSITION 1: The monopoly renter will hold excess capacity in the second period if capacity is relatively cheap ($4k \leq a + m$).

PROPOSITION 2: The monopoly seller will use the identical production plan as the monopoly renter if and only if the monopoly renter uses its capacity fully in the second period. Otherwise the seller will make lower profits than the renter .

PROPOSITION 3: The monopoly seller is less likely than the monopoly renter to hold excess capacity in the second period.

PROPOSITION 4: The monopoly seller's profit, as a function of first-period capacity, may have two local maxima, one involving excess second-period capacity and one not. Its optimal level of capacity is a discontinuous function of its cost parameters when capacity cost $2k$ equals operating cost m .

PROPOSITION 5: The availability of capacity in the second period reduces the monopoly seller's profits, and increases the probability of its holding excess second-period capacity. The monopoly renter is not affected by this availability.

3. Entry Threat

It will henceforth be assumed that the established firm has a monopoly on first-period production, but faces a second-period entry threat. Potential entrants have the same (constant) operating costs m as does the established firm. Their capacity costs are constant, at k per unit. The lower capacity cost reflects the fact that entrants' capacity need only last one period. It turns out that it does not matter if the established firm can also build the cheaper, less durable capacity in the second period. It does matter if they can build such capacity in the first period. These issues are examined below in Section 6. Until then it is assumed that only potential entrants can build the cheaper, less durable capacity.

There are no fixed costs to entrants, and marginal costs are constant. Thus there are no natural barriers to entry due to economies of scale; neither does the established firm have any cost advantage. These assumptions are made to emphasize the role of first-period capacity and production decisions in entry deterrence. Given the constant costs, there is nothing to prevent firms from entering at arbitrarily small levels of production. If the second period is regarded as a "telescoping" of the infinite future, it would seem inconsistent for there to be positive profits to entrants. For unless the number of entrants is limited, or there are artificial barriers to entry, potential entrants will continue to enter as long as profits are being made. Of course, they must

assume that profits will continue to be made after their entry. But it seems reasonable that entry by a new firm at a small enough level will not lower price sufficiently to erode profits.⁸

Here it is assumed that entry occurs until profits to entrants are zero. In effect, the entrants act like a competitive fringe. Each takes price as given, and a large number of them enter, until the price (which is jointly determined by entrants' output and the established firm's reaction to it) equals long-run marginal cost $m+k$. If y denotes the total output of the competitive fringe, when there is an entry threat

$$(8) \quad a - b(x_1 + x_2 + y) \leq m+k \quad \text{with equality if } y > 0$$

The level of output x_2 of the established firm is determined by its reaction function, which depends on whether the established firm is a seller or renter. In either case it behaves like a Cournot duopolist, maximizing profit treating both x_1 and y as given. Of course the established firm could do better by acting as a Stackelberg leader. In such a case the firm would want to increase its own output until y equalled zero or it was constrained by capacity; since the second-period price is determined by equation (8), it is always in the firm's interest to sell as much as possible at the fixed price, which exceeds the short-run marginal cost. But here it is assumed the established firm does not have the advantage of a price leader. If entry occurs, it will react to it à la Cournot. And the only way the firm can deter entry is if its optimal second period production, x_2 , in the absence of any production by the entrants, is such as to imply $a - b(x_1 + x_2) \leq m+k$.⁹ Thus implausible threats of massive retaliation in response to entry will not deter entry; entrants know how the firm will respond.

If the established firm is a renter, it will seek to maximize

$$(9) \quad \Pi_{2r}(x_2; y, c) = [a - b(x_2 + y + c)](x_2 + c) - mx_2 \quad \text{subject to } x_2 \leq c$$

If a seller, it will seek to maximize

$$(10) \quad \Pi_{2s}(x_2; y, c) = [a - b(x_2 + y + c)]x_2 - mx_2 \quad \text{subject to } x_2 \leq c$$

Here it has again been assumed the established firm held no unused capacity in the first-period, so that $x_1 = c$. It can be shown such a policy is always optimal.¹⁰ It also has been assumed that the established firm will wish to rent out in the second period all the output it has produced in the first period. This assumption is not so innocuous, and will be discussed in Section 4 below.

Solving the maximization in (9) and (10) yields the renter's and seller's reaction functions $x_2^r(c, y)$ and $x_2^s(c, y)$.

$$(11) \quad x_2^r(c, y) = \min\left[c, \frac{a - m}{2b} - c - \frac{y}{2}\right]$$

$$(12) \quad x_2^s(c, y) = \min\left[c, \frac{a - m}{2b} - \frac{c + y}{2}\right]$$

Equations (8) and (11) [(8) and (12)] determine the post-entry equilibrium outputs as functions of the established firm's capacity when the established firm is a renter (seller). A comparison of (11) and (12) shows that the seller's reaction function involves more output (for given c, y) than the renter's. The seller expands more aggressively in the second period since it regards reduction in the value of its first-period production as someone else's problem. Suppose now the renter finds it optimal to allow entry; in Section 4 below this will be shown to be possible. Let c be the level of first-period output (and capacity) it chooses. Consider a seller choosing the same level c capacity. Equation (8)

shows that in the post-entry equilibrium $x_2 + y$ must be the same for both seller and renter. But (11) and (12) show the equilibrium production of the established seller in the second period must be at least as large as that of the renter. Since both renter and seller produce the same output in the first period, and face the same price in the second period, the seller's profits must be at least as large. Therefore the following proposition has been proved

PROPOSITION 6: If the established firm is a renter, and finds it optimal to allow entry, then it would have made at least as large profit had it been a seller.

4. Renter's Optimum with an Entry Threat

If the monopoly renter's optimal strategy involves a second-period price below the entrants' long-run marginal cost, then entry is blockaded. From Table 1, this situation occurs when $4k \geq a + m$ and $3k \geq 2a - 3m$, or when $4k \leq a + m$ and $2k \geq a - m$.

As argued above, the renter can deter entry by choosing c and x_2 such that $a - b(c + x_2) = m + k$, and $c \geq x_2$. But for such deterrence to be plausible, the renter must find that x_2 is actually optimal in period 2. Examination of the renter's maximized (9), for the case $y = 0$, shows that the renter will pick x_2 so that his marginal revenue from second-period rentals equals his short-run marginal cost. What if $MR(X) \leq m$ when $a - bX = m + k$? Then the renter will never wish to produce enough output to deter entry in the second period. Such a situation arises if $a - m > 2k$. Then the only way the renter can deter entry is by producing the entire entry-detering output level $c = \frac{a - k - m}{b}$ in the first period.

Even then a problem can arise. Having produced the entry-detering level of output in the first period, the established firm is not obliged to rent it all out in the second period. It will not choose to do so if $MR(c) < 0$ when $a - bc = m + k$. Thus if $2k < a - 2m$, entry cannot be deterred, since the established firm cannot plausibly commit itself to actually putting enough output on the market when costs are so low. Table 3 derives the renter's optimal entry-detering strategy. Note that when $a - m < 2k$, the optimal entry-detering strategy involves full use of capacity in both periods. The reasoning is as follows. If $MR(c + x_2) = m$ and $a - b(c + x_2) = m + k$, then $c = \frac{a - 2k - m}{b}$, which must be negative if $a - m < 2k$. Hence the only feasible entry-detering strategy involves $MR(c + x_2) > m$, which implies full use of capacity ($x_2 = c$) will be chosen in the second period.

PROPOSITION 7: If $2k < a - 2m$ the renter cannot deter entry. If $a - m \geq 2k \geq a - 2m$, the renter can only deter entry by producing the full entry-detering output $\frac{a - k - m}{b}$ in the first period. And if $2k > a - m$, entry deterrence will not involve any excess capacity.

Thus for the renter, entry deterrence will never involve partial use of its capacity in the second period.

If entry deterrence is plausible, then it is optimal for the renter. If $2k > a - m$, the renter could allow entry by reducing capacity. Since the second-period price is still $m + k$, such an action would reduce second-period revenues. But if $c < \frac{a - m - k}{2b}$, which is the entry-detering capacity, $MR(c) > 2(m + k) > m + 2k$, so that first-period revenue would be lost as well.

PROPOSITION 8: If $2k > a - m$, the renter will always deter entry.

If entry is allowed, equations (8) and (11) show

$$(13) \quad x_2 = \text{med}(0, c, \frac{k}{b} - c)$$

Overall profits of the established renter are then¹¹

$$(14) \quad \Pi(c) = \begin{cases} (a - bc)c & \text{if } c \leq \frac{k}{2b} \\ (a - bc - 2k)c + \frac{k^2}{b} & \text{if } \frac{k}{2b} \leq c \leq \frac{k}{b} \\ (a - bc - k)c & \text{if } \frac{k}{b} \leq c \end{cases}$$

Each of the three functions on the right-hand side of (14) are concave. However, the derivative Π' falls at $c = \frac{k}{2b}$ and jumps at $\frac{k}{b}$.¹² Thus there are possibilities of multiple local maxima, if $\Pi'_- < 0$ and $\Pi'_+ > 0$ at $c = \frac{k}{b}$. From (14) this possibility occurs when $3k < a < 4k$. When $3k \geq a$, there is a unique local optimum at $c = \frac{a - k}{2b}$. When $3k < a < 4k$, profits at local optima must be compared. The results of this comparison¹³ are in Table 4, where it is shown that when $\frac{7}{2}k > a > 3k$, it is optimal to have excess capacity, but produce something in the second period. When $a > \frac{7}{2}k$, it is optimal not to produce anything in the second period if entry is to be allowed.

However, notice that under this last policy, the output of the competitive fringe will be $\frac{a - 2m - k}{2b}$. This cannot be done if $a - 2m - k \leq 0$. Therefore if $a - 2m - k \leq 0$ and $a < 4k$, the best entry-allowing policy is the other local optimum. The best entry-allowing policy with $x_2 = 0$ is dominated by entry deterrence. If $a - 2m - k \leq 0$ and $a > 4k$, then any entry-allowing strategy will be dominated by entry deterrence. Of course, proposition 8 indicates entry deterrence is always superior for the renter if $a - 2k - m \leq 0$. A comparison of profits in Tables 3 and 4 yields Figure 4, which shows the optimal policies for the renter. Note that entry may be allowed or deterred, and that excess capacity is consistent with either outcome.

5. Seller's Optimum With an Entry Threat

Like the renter, the seller may blockade entry if its optimal policy as a monopolist involves a second-period price of $m+k$ or less. For the seller, entry is more likely to be blockaded than for the renter, since the former's cumulative production (as a monopolist) is at least as large as the latter's. But in Section 2 above it was shown that the monopoly seller will have multiple local equilibria if $8m - 2a \leq 12k \leq a + 5m$. Since the local optimum with excess capacity involves more cumulative output than the local optimum implying full use of capacity, the former is more likely to deter entry. If $3k \leq 2a - 3m$, the latter policy will not blockade entry, as can be confirmed from Table 2. But if $2k > m$, it is more profitable for the monopoly seller. Finally, if $6k \leq 3a - 5m$, the other local maximum (involving excess capacity) does blockade entry. So in the area bounded by $6k \leq 3a - 5m$, $12k \leq a + 5m$, $2k > m$ and $3k \leq 2a - 3m$ there are two possible optimal strategies to deter entry: an excess-capacity policy which involves a price strictly below the entry-detering level, and is locally (but not globally) optimal for a monopolist, and a policy with full use of capacity, which is not optimal for a monopolist. Comparison of profits¹⁴ indicates the former policy is more profitable in the area marked by an asterisk in Figure 5.

Aside from the peculiarity just discussed, the seller's choice of policy when confronted by an entry threat is simpler than the renter's (although not necessarily more profitable). Unlike the renter, the seller is always able to deter entry. Suppose $a - bc = m + k - \epsilon$, where ϵ is small. Then the seller will wish to produce sufficient output x_2 in the second period so that $a - bc - 2bx_2 = m$. For small enough ϵ , this strategy will clearly involve a large enough x_2 to deter entry. Of course, it may also be rather costly if k is large, since a heavy initial capacity investment may be required.

When entry is not blockaded, deterrence implies picking a capacity level c such that $a - b(c + x_2) = m + k$, where x_2 is the established firm's second period output, determined from equation (6) above ($x_2 = \min(c, \frac{a - m - bc}{2b})$). Table 5 shows the entry deterring policies for the monopoly seller when entry is not blockaded. Not surprisingly, entry deterrence will involve excess capacity in the second period when capacity is cheap ($3k \leq a - m$).

If the established seller allows entry, it must hold excess capacity in the second period. If it fully used capacity in the second period, then $x_2 = c$, so that $a - 2bc > a - bc - bx_2 - by = m + k$. Consider now a slight expansion of capacity. The added first-period marginal revenue is proportional to $a - 2bc$; if the capacity is fully used in the second period the added second-period revenue is $2(m + k)$, and added costs in both periods are proportional to $2(m + k)$, so that the change increases profits. If the firm were on the margin of not using the capacity fully (i.e., $c = \frac{a - m - bc}{2b}$), the added second-period revenue would be only $(m + k)$ and the added cost only $m + 2k$, so that the addition would still be profitable.

PROPOSITION 9: If the seller allows entry, it will hold excess capacity in the second period.

When is entry allowance optimal? In the second period, x_2 solves $a - bc - by - 2bx_2 = m$. Since $a - b(c + y + x_2) = m + k$, therefore $x_2 = \frac{k}{b}$, independent of capacity. Thus a small increase in capacity will decrease output of the entrants by the same amount. The marginal profit of such a change is thus $(a - 2bc) + (m + k) - (m + 2k)$; the first term is marginal first-period revenue, the second is marginal second-period revenue, the third marginal cost. This marginal profit is clearly a declining function of c . So entry should be allowed if this

marginal profit is negative when c equals the entry-detering level $\frac{a - m - 2k}{b}$.

Such a condition is equivalent to $a > 3k + 2m$. And if entry is allowed, the optimal capacity involves $c = \frac{a - k}{2b}$, as in Table 6.

PROPOSITION 10: The seller will allow entry if costs are low relative to demand:
if $a \leq 3k + 2m$. If entry is allowed, the seller's capacity
second-period output and profit are independent of operating costs.

Figures 4 and 5 show how the renter's and seller's optimal policies vary with the cost and demand parameters. They also indicate

PROPOSITION 11: The seller is more likely than the renter to deter entry. (That is, if the renter deters entry, so will the seller.)

This conclusion follows from the fact that the seller is better able to commit itself to the high future output necessary to deter entry. Figure 6 shows the comparative profitability of renting and selling. If demand is high enough, selling must be more profitable--as proposition 6 above indicated. If the renter deters entry, and fully uses capacity, then the seller will do exactly the same thing. But when entry is blockaded for the renter, or when the renter deters entry while not producing anything in the second period, it may make more profit than the seller. Figure 6 also shows that a necessary condition for renting to be more profitable is $m > k$, or capacity cost of the entrants to be less than operating cost.

Figure 7 shows the combined effect of selling and an entry threat on capacity. That is, it compares the capacity investment of a seller facing an entry threat with that of a monopoly renter. Since the entry threat tends to increase capacity, while the seller's commitment problem tends to decrease it, the comparison is a priori ambiguous. But Figure 7 shows that if demand or capacity cost is high enough, the "entry threat effect" predominates. Figure 7 also shows that the combination of entry threat and selling may create excess capacity, or

eliminate it. This is not surprising; here excess capacity is not a device to threaten entrants, but a consequence of the assumed irrevocability of the first-period capacity decision.

6. Variable Durability of Capacity

The presence of excess capacity (under some circumstances) in this model is not surprising. As previous noted it is due not to the strategy of entry deterrence but to the technology. It has been assumed that the established firm must build its capacity in the first period, and build it to last for 2 periods. The entrants' capacity has been assumed to be half as durable and cost half as much. In this section, the implications of relaxing some of these assumptions will be discussed.

First, note that it does not matter that the established firm is not able to build capacity in the second period. If it could add capacity in the second period, at a cost of k per unit, it would never do so in the presence of an entry threat. Price in the second period cannot exceed $m + k$. Thus the appropriate marginal revenue ($a - bx_1 - by - 2bx_2$ for the seller, $a - 2bx_1 - by - 2bx_2$ for the renter) must be less than the marginal cost $m + k$ of output produced from new capacity. The entry threat makes plausible the promise of a seller not to expand capacity. As Section 2 above demonstrated, the seller would always choose to make such a commitment in the absence of an entry threat by expanding first-period output. Here the response to the entry threat serves to make such a commitment. This result would occur regardless of the cost of second-period capacity, as long as both entrants and the established firm had the same cost. If entrants' capacity cost $\alpha k (\alpha > 1)$, the established firm would never wish to add capacity if its costs were αk or more.

PROPOSITION 12: The established firm (whether seller or renter) will never wish to add capacity in the second period when there is an entry threat.

However, first-period capacity is another matter. Results change drastically if the established firm can build less durable capacity in the first period. Suppose capacity which only last one period can be built at a unit cost of αk ($1 \leq \alpha < 2$) in the first period. Then clearly no excess capacity will be observed in the second period, irrespective of whether the firm is a monopolist or threatened by entry, renter or seller. For if $x_1 > x_2$, replacing ε units of durable capacity with ε units of less-durable capacity in period 1, lower costs by $(2-\alpha)\varepsilon$ without affecting anything else. In other words, excess capacity is a result of the assumption that there is no cost advantage to the established firm to building less durable capacity. Expressed otherwise, it is a short-run phenomenon. If the length of period in the two-period model presented here is long enough so that all factors can be varied (even at some cost), excess capacity will not be observed in a rational expectations equilibrium.

Moreover, even if capacity for the established firm can only be built to last two periods, the ownership of the capacity can be changed. If the established firm chooses an entry-allowing strategy which involves excess capacity, it could increase profits in the second period by selling off excess capacity (at the market price of k) to its rivals. Such sales will not affect the level of entry; they merely replace new equipment with older, unused equipment.

Of course the very notion of "unused capacity" depends on the fixed-proportions technology assumed here. The more general technology considered, for example, in Dixit (1980), admits as an analogue only factor proportions

which differ from those dictated by long-run cost minimization. With such technology, the durable-good monopolist confronted by an entry threat would no doubt be observed using such a distorted factor mix in the second period, under some circumstances. But again, these distortions would arise only if adjusting the level of one of the factors between periods were costly.

If all agents are rational, and threats must be plausible to be effective, then any sort of excess capacity must be a short-run phenomenon.

7. Concluding Remarks

This paper has examined the roles of product durability and fixity of capacity in entry deterrence. In a sense durability of the output is a substitute for durability of capacity, a point made more precisely elsewhere.¹⁵ But there is an interaction of the two roles. When the product is durable, producers who sell their output have an incentive to reduce capacity to convince buyers of high resale value. This incentive is reduced by the threat of entry. In fact if entry is to be allowed, and buyers know it, the established firm's reduced capacity is no longer a guarantee of low future output. Nonetheless there may be levels of capacity which both deter entry, and convince buyers of a high resale value. These are shown in Figure 7.

In the absence of an entry threat, a producer who rents his output is better off than one who sells, due to the seller's problem in committing himself to low future output. But an entry threat may reverse this relative profitability, since the seller's reaction to entry (in the post-entry game) is more aggressive than renter's. The seller sees the capital losses on existing products due to his own expansion as falling on his last-period customers. This induces greater expansion than for the renter. Also, entry

deterrence is easier for a seller: the renter may be unable to convince prospective entrants that it will really use all of its capacity, since second-period production reduces the rental value of its first-period production. Figure 6 illustrates the relative profitability of renting and selling when there is an entry threat.

Excess capacity arises frequently in the models presented here-- whether the established firm is a seller or renter, whether there is an entry threat or not and whether entry is deterred or allowed. Thus although excess capacity is consistent with entry deterrence, it is consistent with many other outcomes. And it is more consequence than cause of the deterred entry. Excess capacity also depends crucially on the assumptions about the technology of altering capacity; in essence it is a short-run phenomenon in all cases considered.

Footnotes

¹Implicit in the formulation below is that the monopolist renter wishes to rent out all its available output in each period. In the absence of an entry threat this assumption will always be true. The firm would want to withhold output (in either period) only when marginal revenue is negative, in which case it would be better off producing less. The assumption is not always true in the presence of an entry threat, as noted in Section 3 below.

²Derivation of all the results are available in an Appendix; for the most part these computations are quite straightforward.

³If $x_1 < c$ and $x_2 < c$, clearly lowering capacity will lower costs without lowering revenue. But if $x_2 = c$, then $a - b(x_1 + 2x_2) \geq m$. Then if $x_1 < c$, $a - 2bx_1 > m$, so that using capacity more in the first period would increase first-period revenue more than operating cost. This increase would increase second period revenue by $a - 2bx_1 - x_2 \geq m > 0$, so would be profitable. Hence $x_1 < c$ cannot be optimal.

⁴If $c \leq \frac{a-m}{3b}$, $\pi = (a-bc)c + (a-2bc-m)2c - 2kc$, so $\pi' = 3a - 2m - 2k - 10bc$, $\pi'' = -10b$. If $c > \frac{a-m}{3b}$, $\pi = (a-bc)c + (\frac{a}{2} - \frac{m}{2} - \frac{bc}{2})(\frac{a-m-bc}{2b}) - 2kc$, so $\pi' = a - 2k - \frac{5}{2}bc$, $\pi'' = -\frac{5}{2}b$. At $c = \frac{a-m}{3b}$ the left-hand derivative is $\frac{-a+4m-6k}{3}$, the right-hand derivative $\frac{a+5m-12k}{6}$. Thus the left-hand derivative is smaller if $-2a+8m-12k \leq 2a+5m-12k$, or $a > m$. Since $c = \frac{a-m}{3b}$, $c > 0$ is sufficient.

⁵See footnote 4 above.

⁶An appendix containing these computations is available from the author.

⁷If capacity is added in the second period, then $x_1 \leq x_2$. Adding more capacity in period 1 will raise first-period revenues by $a - 2bx_1$, and second-period revenue by $a - 2bx_1 - 2bx_2$ (since it will be used both periods). The added costs are $2m + 2k$, so the change in revenue is $2a - 4bx_1 - 2bx_2 - 2m + 2k$. Since $a - bx_1 - 2bx_2 = m + \alpha k$, $a - 2bx_1 - bx_2 > m + \alpha k$, so the change in revenue is positive. Thus no optimum can occur when capacity will be added in the second period.

⁸If existing firms' reaction functions are continuous in the new entrant's output then this conclusion must hold.

⁹I am thus requiring that the post-entry equilibrium be perfect.

¹⁰Equation (8) shows entrants' output depends on the established firm's actual production, not its capacity. Thus if $c > x_1$, and $x_2 = c$ raising x_1 will lower y , not affect x_2 , and not alter the second-period price $m + k$. The net gain in revenue will be $(a - 2bx_1) + (m + k) - m$. If $x_2 = c$, then $a - bx_1 - 2bx_2 - by \geq m$, so $a - 2bx_1 > 0$ and the net gain in revenue is positive. If $c > x_1$ and $c > x_2$, clearly lowering c will lower costs without affecting anything else.

¹¹If $c \leq \frac{k}{2b}$, $x_2 = c$. If $c > \frac{k}{2b}$, $x_2 \leq c$, so $x_2 = \max(\frac{k}{b} - c, 0)$. In all 3 cases the second-period price is $m + k$, and the first-period rental price $a - bc$.

¹² $\pi' = a - 2bc$ if $c \leq \frac{k}{2b}$, $\pi' = a - 2bc - 2k$ if $\frac{k}{2b} \leq c \leq \frac{k}{b}$, $\pi' = a - 2bc - k$ if $c > \frac{k}{b}$.

¹³Contained in an appendix, available from the author.

¹⁴Contained in an appendix available from the author.

¹⁵See Bucovetsky and Chilton (1983).

Table 1Optimum for Monopoly Renter

$$4k > a + m \quad x_1 = 0 \quad c = 0$$

$$3a < 2(k+m) \quad x_2 = 0$$

$$4k > a + m \quad c = \frac{3a - 2m - 2k}{10b}$$

$$3a \geq 2(k+m) \quad x_1 = \frac{3a - 2m - 2k}{10b} \quad \phi(x_1) = \frac{7a + 2m + 2k}{10}$$

$$x_2 = \frac{3a - 2m - 2k}{10b} \quad \phi(X) = \frac{2a - 2m + 2k}{5}$$

$$X = \frac{3a - 2m - 2k}{5b} \quad p_1 = \frac{11a + 6m + 6k}{10}$$

$$\Pi = \frac{(3a - 2m - 2k)^2}{20b}$$

$$4k \leq a + m \quad x_1 = 0 \quad c = 0$$

$$2a < m + 2k \quad x_2 = 0$$

$$4k \leq a + m \quad c = \frac{2a - m - 2k}{4b}$$

$$2a \geq m + 2k \quad x_1 = \frac{2a - m - 2k}{4b} \quad \phi(x_1) = \frac{2a + m + 2k}{4}$$

$$2k < m \quad x_2 = 0 \quad \phi(X) = \frac{2a + m + 2k}{4}$$

$$X = \frac{2a - m - 2k}{4b} \quad p_1 = \frac{2a + m + 2k}{2}$$

$$\Pi = \frac{(2a - m - 2k)^2}{8b}$$

$$4k \leq a + m \quad c = \frac{a - 2k}{2b}$$

$$2a \geq m + 2k \quad x_1 = \frac{a - 2k}{2b} \quad \phi(x_1) = \frac{a + 2k}{2}$$

$$2k \geq m \quad x_2 = \frac{2k - m}{2b} \quad \phi(X) = \frac{a + m}{2}$$

$$X = \frac{a - m}{2b} \quad p_1 = \frac{2a + m + 2k}{2}$$

$$\Pi = \frac{(a-m)^2 + (a-2k)^2}{4b}$$

Table 2Seller: No Entry Threat

$$k > \frac{m}{2}$$

$$c = \frac{3a - 2m - 2k}{10b}$$

$$3a \geq 2k + m$$

$$x_1 = \frac{3a - 2m - 2k}{10b}$$

$$\phi(x_1) = \frac{7a + 2m + 2k}{10}$$

$$x_2 = \frac{3a - 2m - 2k}{10b}$$

$$\phi(X) = \frac{2a + 2m + 2k}{5}$$

$$X = \frac{3a - 2m - 2k}{5b}$$

$$p_1 = \frac{11a + 6m + 6k}{10}$$

$$\Pi = \frac{(3a - 2m - 2k)^2}{20b}$$

$$k \leq \frac{m}{2}$$

$$c = \frac{2a - 4k}{5b}$$

$$4k \geq 5m - 3a$$

$$x_1 = \frac{2a - 4k}{5b}$$

$$\phi(x) = \frac{3a + 4k}{5}$$

$$x_2 = \frac{3a - 5m + 4k}{10b}$$

$$\phi(X) = \frac{3a + 5m + 4k}{10}$$

$$X = \frac{7a - 5m - 4k}{10b}$$

$$p_1 = \frac{9a + 5m + 12k}{10}$$

$$\Pi = \frac{(3a - 5m + 4k)^2}{100b} + \frac{(a - 2k)(36a - 20m - 32k)}{100b}$$

$$k \leq \frac{m}{2}$$

$$c = \frac{a - m}{b}$$

$$4k < 5m - 3a$$

$$x_1 = \frac{a - m}{b}$$

$$\phi(x) = m$$

$$2a > 3m - 2k$$

$$x_2 = 0$$

$$\phi(X) = m$$

$$X = \frac{a - m}{b}$$

$$p_1 = 2m$$

$$\Pi = \frac{(m - 2k)(a - m)}{b}$$

$$k \leq \frac{m}{2}$$

$$c = \frac{2a - m - 2k}{4b}$$

$$4k < 5m - 3a$$

$$x_1 = \frac{2a - m - 2k}{4b}$$

$$\phi(x) = \frac{2a + m + 2k}{4}$$

$$2a > m + 2k$$

$$x_2 = 0$$

$$\phi(X) = \frac{2a + m + 2k}{4}$$

$$2a \leq 3m - 2k$$

$$X = \frac{2a - m - 2k}{4b}$$

$$p_1 = \frac{2a + m + k}{2}$$

$$\Pi = \frac{(2a - m - 2k)^2}{8b}$$

Table 3Renter: Entry Deterring

$$2k \geq a - m$$

$$c = \frac{a - k - m}{2b}$$

$$x_1 = \frac{a - k - m}{2b}$$

$$\phi(x_1) = \frac{a + k + m}{2}$$

$$x_2 = \frac{a - k - m}{2b}$$

$$\phi(X) = k + m$$

$$X = \frac{a - k - m}{b}$$

$$p_1 = \frac{a + 3k + 3m}{2}$$

$$\Pi = \frac{a^2 - (k + m)^2}{4b}$$

$$2k < a - m$$

$$c = \frac{a - k - m}{b}$$

$$2k \geq a - 2m$$

$$x_1 = \frac{a - k - m}{b}$$

$$\phi(x_1) = k + m$$

$$x_2 = 0$$

$$\phi(X) = k + m$$

$$X = \frac{a - k - m}{b}$$

$$p_1 = 2k + 2m$$

$$\Pi = \frac{m(a - k - m)}{b}$$

$$2k < a - 2m$$

no deterrence possible

$$\text{if } \phi(X) \leq k + m \quad X \geq \frac{a - k - m}{b}$$

$$MR(X) = a - 2bX \leq 2k + 2m - a \leq 0$$

Table 4Renter: Entry Allowing

$$k < a < 3k$$

$$c = \frac{k}{2b}$$

$$x_1 = \frac{k}{2b}$$

$$x_2 = \frac{k}{2b}$$

$$x = \frac{k}{b}$$

$$y = \frac{a - 2k - m}{b}$$

$$\phi(x_1) = \frac{2a - k}{2}$$

$$p_1 = \frac{2a + k + 2m}{2}$$

$$\Pi = \frac{k(2a - k)}{4b}$$

$$\frac{7}{2}k > a > 3k$$

$$a - 2m - k > 0$$

or

$$4k > a$$

$$a - 2m - k \leq 0$$

$$c = \frac{a - 2k}{2b}$$

$$x_1 = \frac{a - 2k}{2b}$$

$$x_2 = \frac{4k - a}{2b}$$

$$x = \frac{k}{b}$$

$$y = \frac{a - 2k - m}{b}$$

$$\phi(x_1) = \frac{a + 2k}{2}$$

$$p_1 = \frac{a + 4k + 2m}{2}$$

$$\Pi = \frac{(a - 2k)^2 + 4k^2}{4b}$$

$$a > \frac{7}{2}k$$

$$a - m - 2k > 0$$

$$c = \frac{a - k}{2b}$$

$$x_1 = \frac{a - k}{2b}$$

$$x_2 = 0$$

$$x = \frac{a - k}{2b}$$

$$y = \frac{a - 2m - k}{2b}$$

$$\phi(x_1) = \frac{a + k}{2}$$

$$p_1 = \frac{a + 3k + 2m}{2b}$$

$$\Pi = \frac{(a - k)^2}{4b}$$

Table 5Seller: Entry Deterring

$$3k > a - m$$

$$c = \frac{a - k - m}{2b}$$

$$x_1 = \frac{a - k - m}{2b}$$

$$\phi(x_1) = \frac{a + k + m}{2}$$

$$x_2 = \frac{a - k - m}{2b}$$

$$\phi(X) = k + m$$

$$X = \frac{a - k - m}{b}$$

$$p_1 = \frac{a + 3k + 3m}{2}$$

$$\Pi = \frac{a^2 - (k + m)^2}{4b}$$

$$3k \leq a - m$$

$$c = \frac{a - 2k - m}{b}$$

$$x_1 = \frac{a - 2k - m}{b}$$

$$\phi(x_1) = m + 2k$$

$$x_2 = \frac{k}{b}$$

$$\phi(X) = k + m$$

$$X = \frac{a - k - m}{b}$$

$$p_1 = 2m + 3k$$

$$\Pi = \frac{k^2 + (m + k)(a - 2k - m)}{b}$$

Table 6Seller: Entry Allowing

$$a > 3k + 2m$$

$$c = \frac{a - k}{2b}$$

$$x_1 = \frac{a - k}{2b}$$

$$x_2 = \frac{k}{b}$$

$$X = \frac{a + k}{2b}$$

$$y = \frac{a - 2m - 3k}{2b}$$

$$\phi(x_1) = \frac{a + k}{2}$$

$$p_1 = \frac{a + 3k + 2m}{2}$$

$$\Pi = \frac{a^2 - 2ak + 5k^2}{4b}$$

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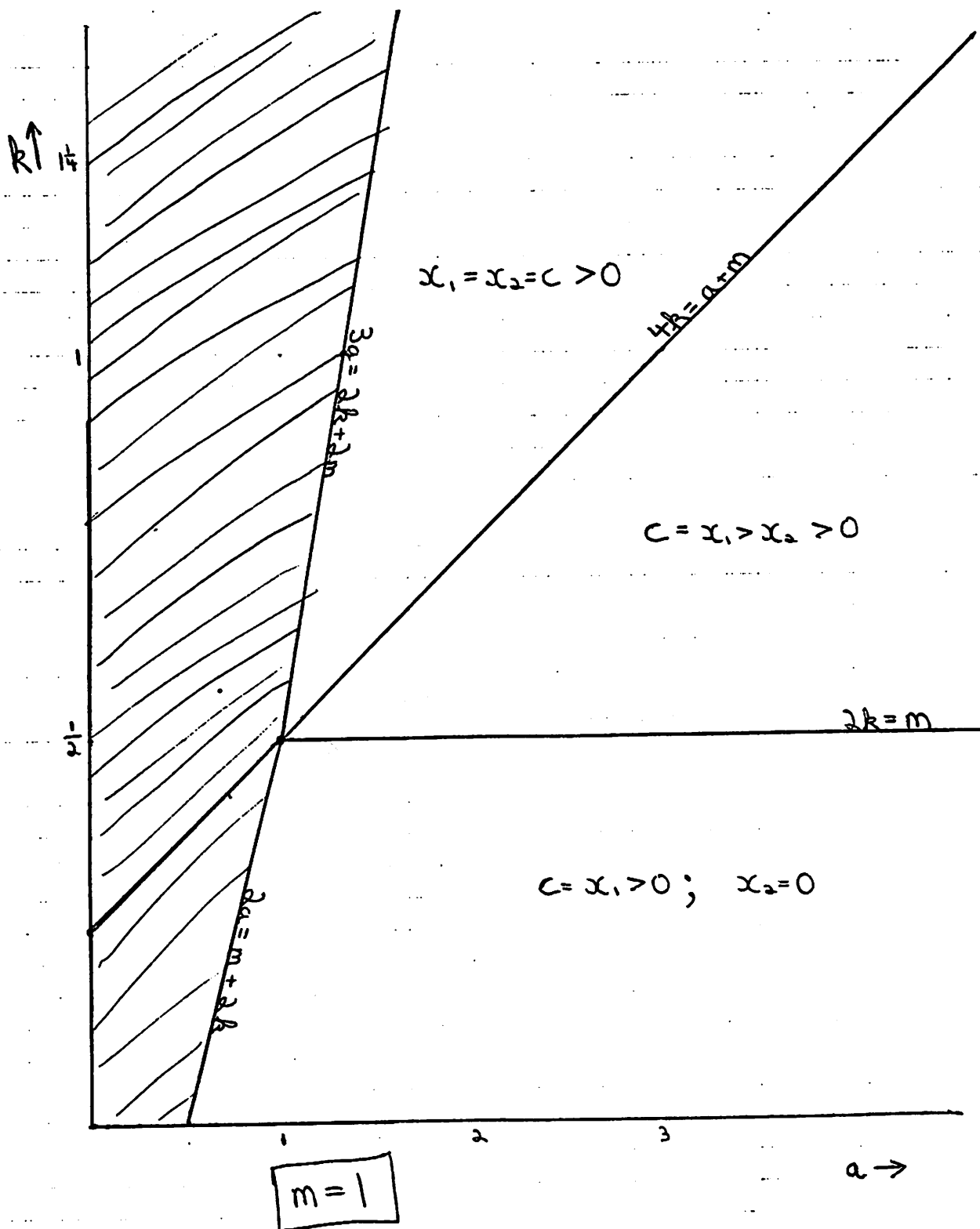


FIGURE 1 : MONOPOLY RENTER
(zero production in shaded area)

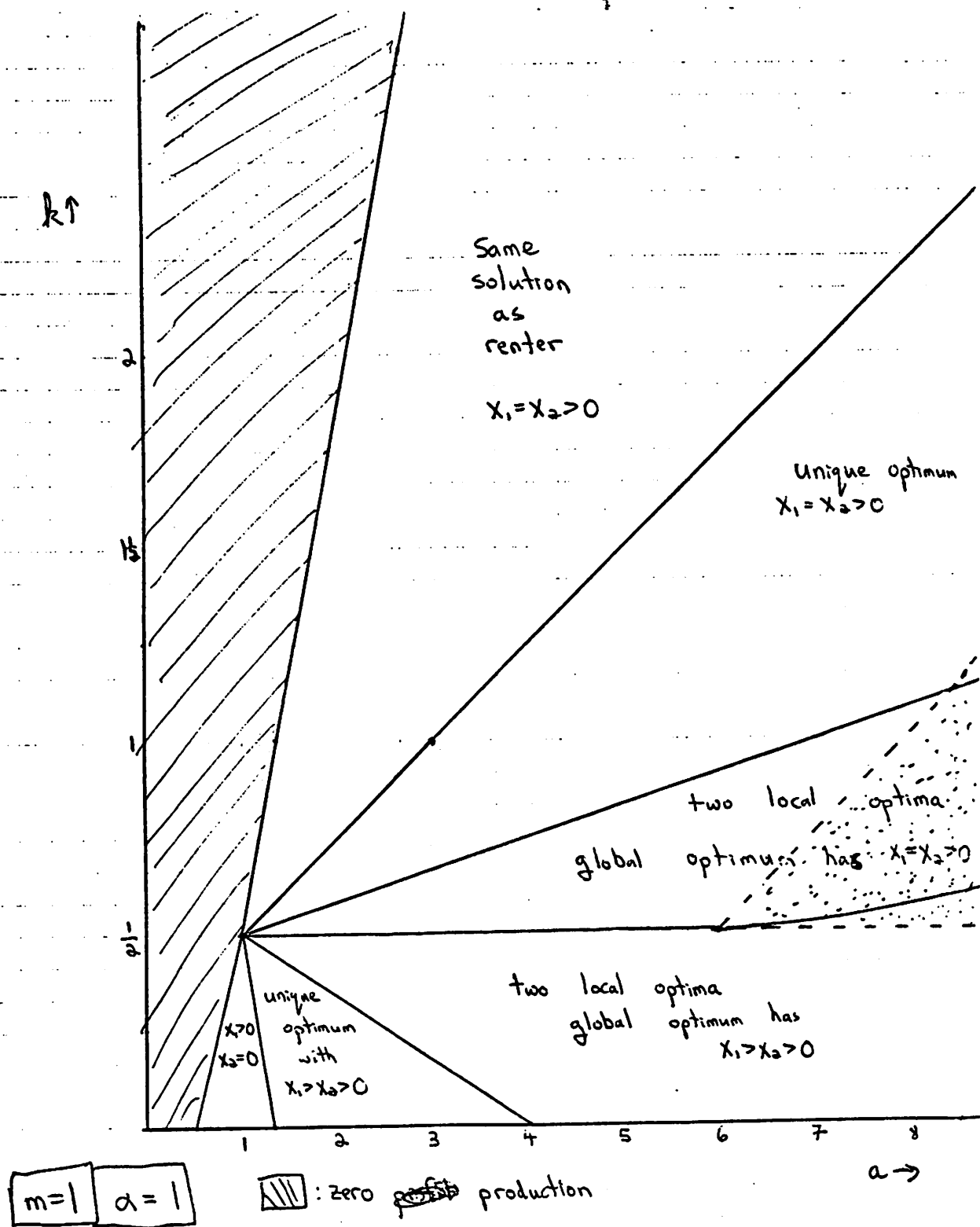
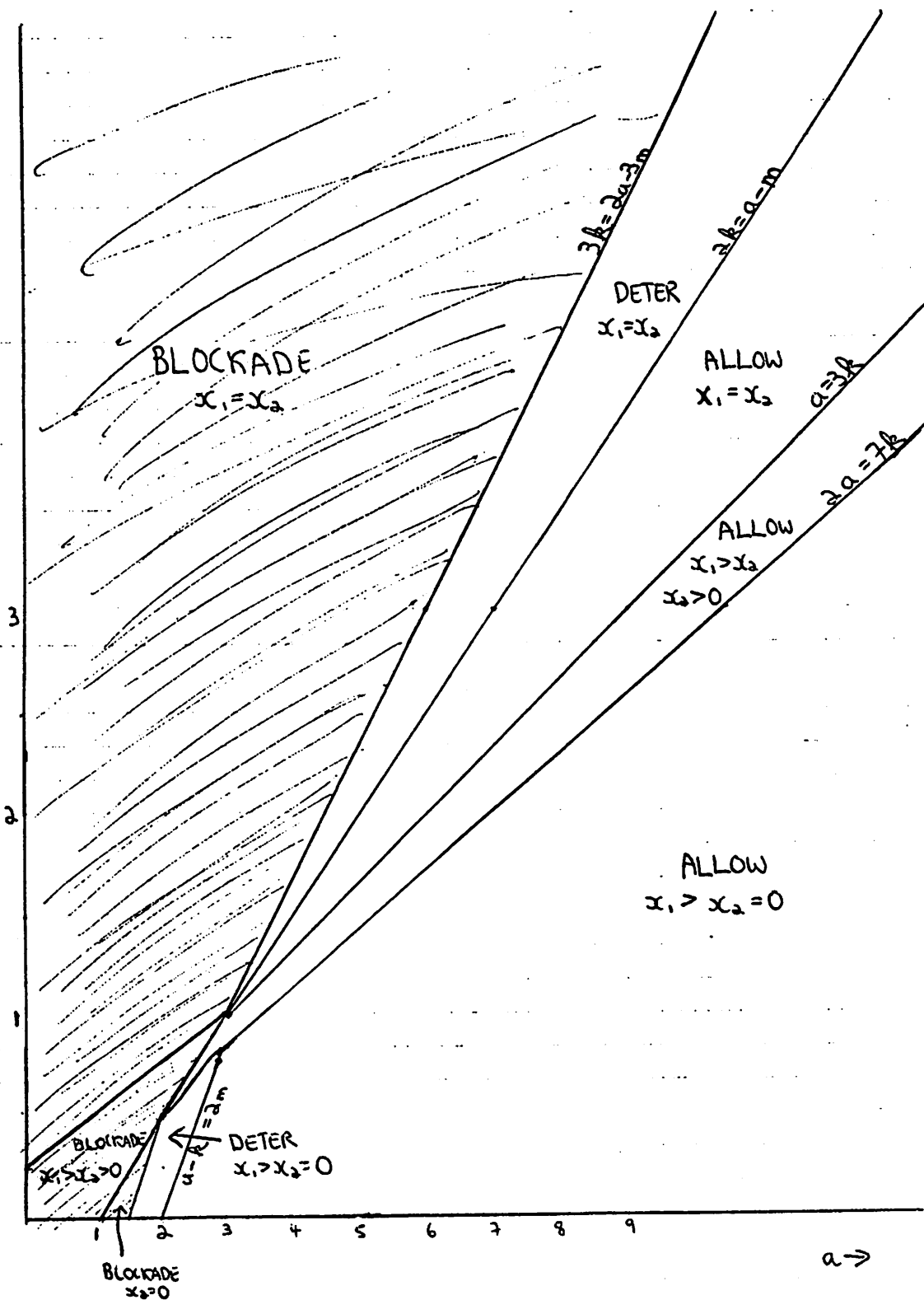


FIGURE 3: MONOPOLY SELLER WHEN CAPACITY CAN BE ADDED IN PERIOD 2 AT A UNIT COST OF α

: area where availability of capacity lowers profits

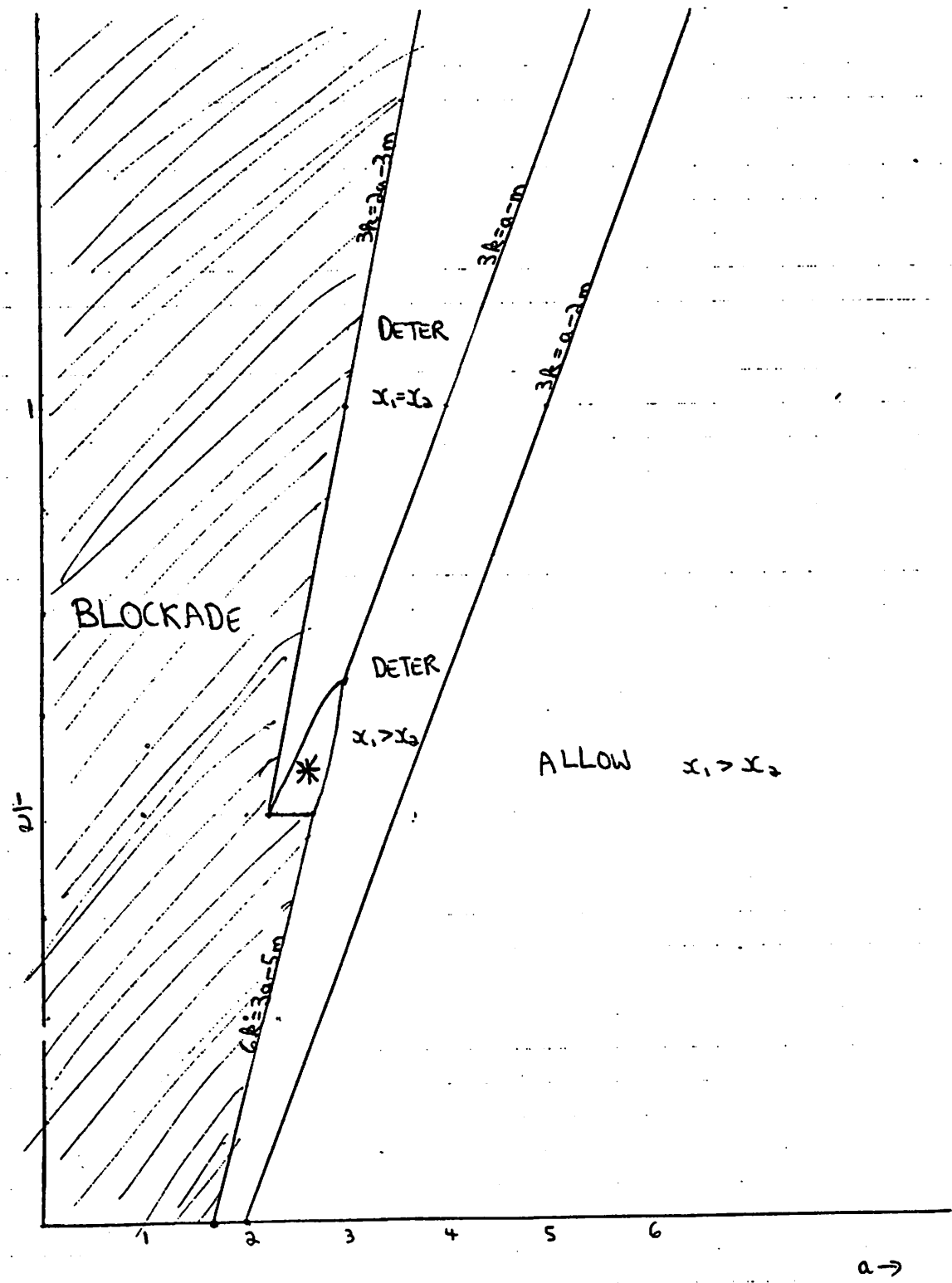
$R \uparrow$



$m=1$

FIGURE 4: RENTER WITH A SECOND-PERIOD ENTRY THREAT
(entry blocked in shaded area)

R_1



$m=1$

FIGURE 5: SELLER WITH A SECOND-PERIOD ENTRY THREAT (entry blockaded in shaded area)

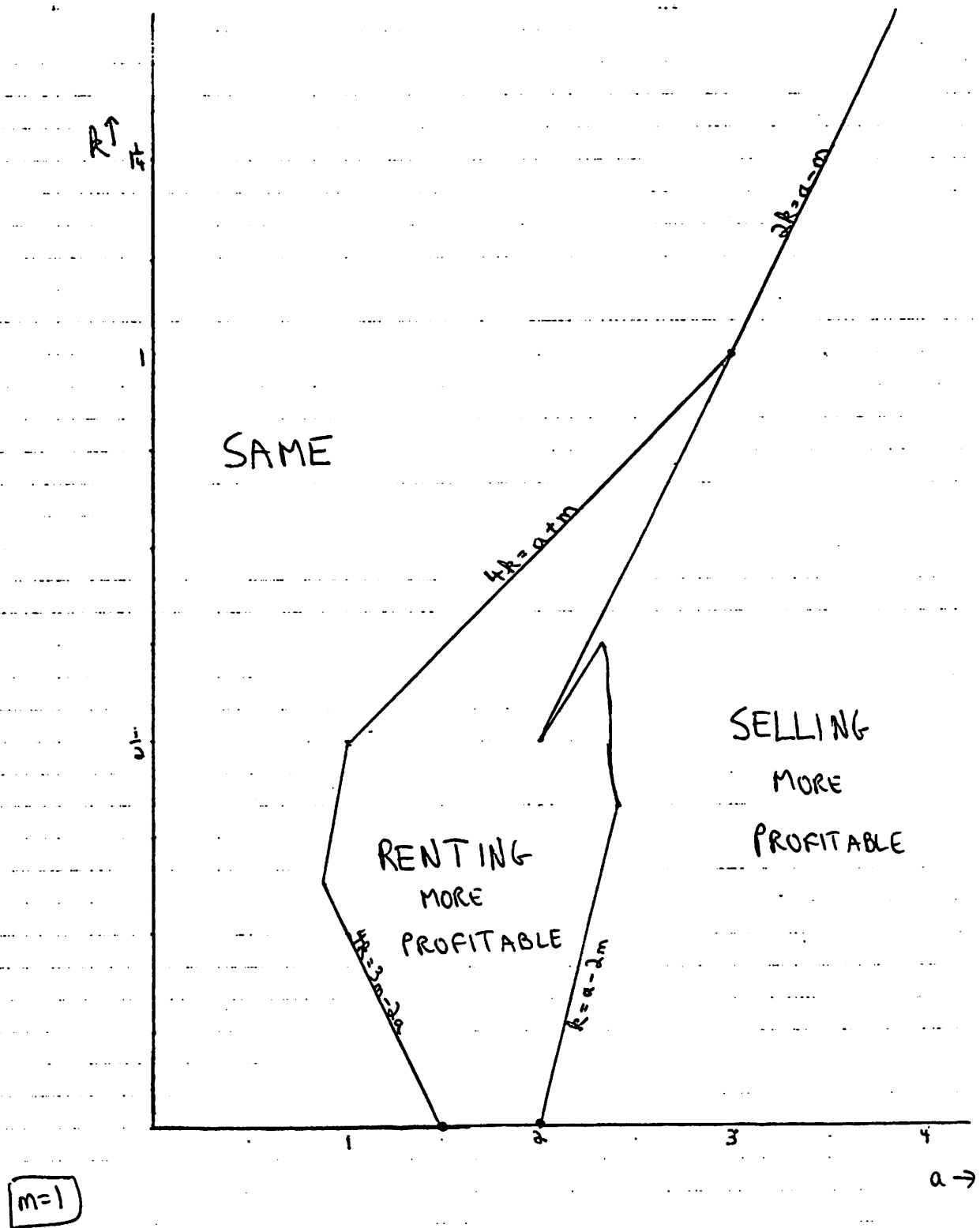


FIGURE 6: COMPARISON OF PROFITABILITY OF
 SELLING RENTING WHEN THERE IS
 AN ENTRY THREAT

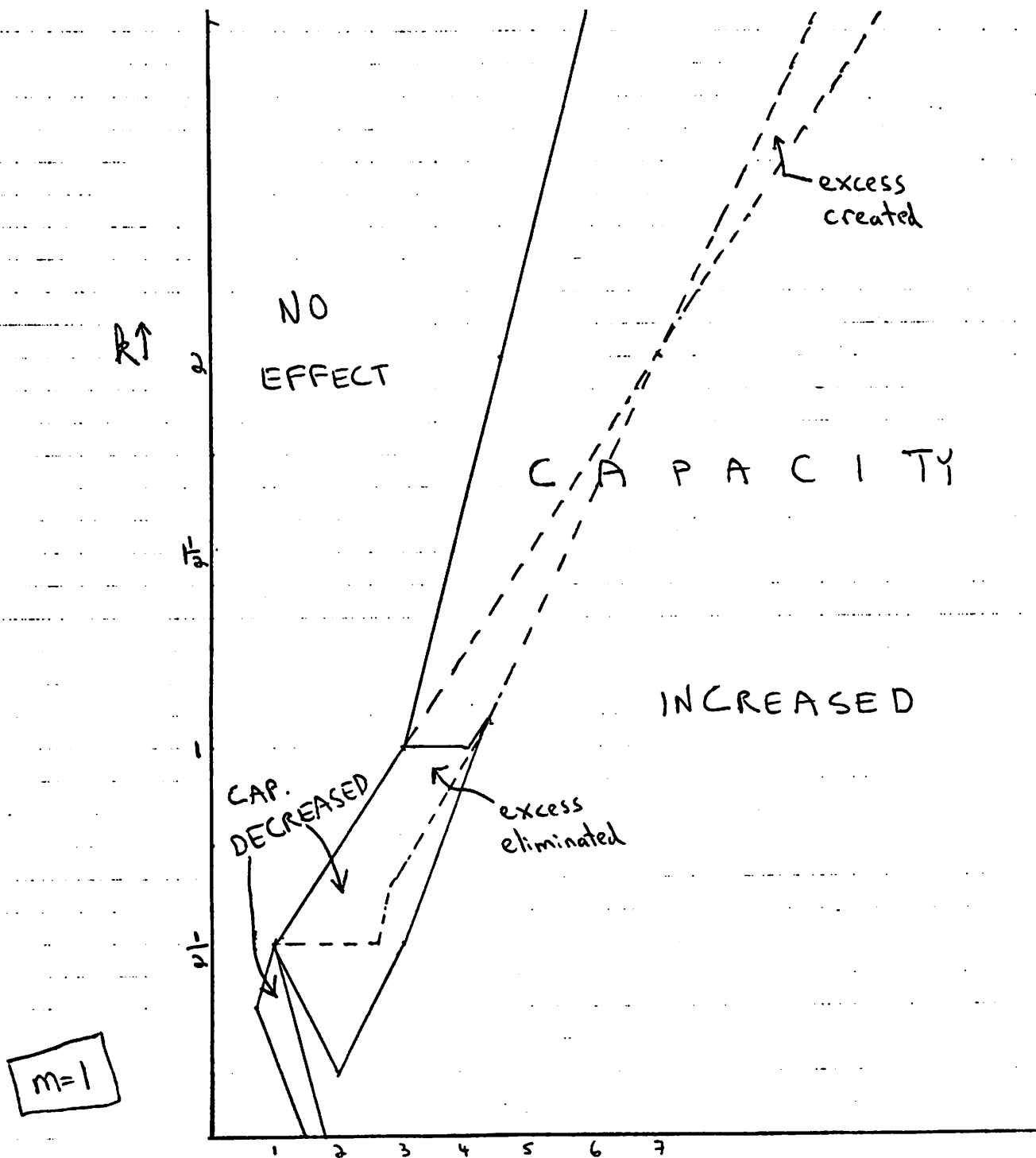


FIGURE 7: EFFECT OF ENTRY THREAT AND SELLING ON CAPACITY

(i.e. comparison of capacity of seller threatened by entry with monopoly renter)
 dotted lines indicate regions where threatened seller has excess capacity but not monopoly renter ("excess created") or vice versa